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(54) **A process and apparatus for the combined thermal treatment of metallic materials and articles.**

(57) A process for the treatment of metallic materials and articles comprising, in combination with a known type thermal treatment, the exposure of the article to the aeroacoustic action of a pulse gaseous stream in the field of sonic frequencies, at an acoustic pressure of at least 150 dB. Said action is preferably achieved arranging the article to be treated at the interior of the resonator of a suitable apparatus, operating as a gasdynamic acoustic generator.

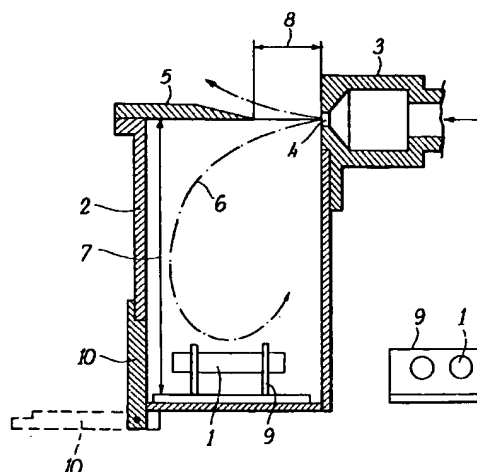


FIG. 1

EP 0 524 156 A1

The present invention relates to a process and apparatus for the combined thermal treatment of metallic materials and articles. More particularly, the invention relates to a non conventional type of a not only thermal treatment for metallic and alloy materials, or for the articles produced with said materials, which has the effect of improving their performance under the mechanical profile and/or of rendering the achievement of pre-established levels of such performance cheaper.

The treatments which metallic materials are usually subjected to in order to modify their strength and workability mechanical characteristics, their resistance to heat and to corrosion, and, in general, the various technologically interesting physical and chemical properties are very numerous and different according to the type of the starting material and the properties that one desires to introduce or improve.

The fundamental actions that are exerted upon metallic materials in industrial processes are, generally, of a mechanical (plastic deformation), thermal or chemical type, and, according to the exerted actions, conventional treatments can be grouped into some basic classes: plastic deformation treatments, thermal treatments, thermal-mechanical treatments and thermal-chemical treatments.

The processings of the first mentioned class consist in inducing in the material a cold deformation state (work-hardening) that increases its mechanical strength and reduces its capability to undergo further plastic deformations. Such an effect can be explained considering that the deformation increases the density of defects of the crystal structure (dislocations, vacancies, interstitial atoms) at such a level that their further displacement caused by further stresses turns out to be strongly hindered.

Thermal treatments constitute, certainly, the most numerous and articulate group, and find their widest application in steel industry. According to the specifications, by thermal treatment an operation or a succession of operations is meant, whereby a metal or a metallic alloy are subjected, below the melting point or range, to one or more thermal cycles each made up of a heating, a permanency at a certain temperature and a cooling, with pre-established temperatures, time durations and temperature change rates, in order to impart determinate properties to the material. The effect of such a combination of operations is that of causing modifications in the structure and in the composition of the phases present in the material.

The combination of operations of these first two classes originates thermal-mechanical treatments, whereas in the thermal-chemical ones, the most typical example whereof is the case-hardening of steels, the action of temperature is combined with the saturation of the material, at a surface level, with determinate elements (e.g. carbon, nitrogen, aluminum, chromium in the case of the steels) in order to impart determinate surface properties (e.g. hardness, the resistance to wear or to corrosion) to the product.

The main types of the traditional thermal treatments for metal alloys are annealing, normalizing, hardening, tempering and ageing. The first essentially consists in heating the article to a temperature in the neighbourhood of the critical range (in correspondence with which the transformation from a solid phase to the other takes place), in letting it remain in it for a fairly prolonged time and in slowly cooling it, in order to obtain, for instance, a better homogenizing, the elimination or the reduction of internal stresses, an easier workability.

Normalizing is carried out to homogenize and refine the crystal grain, and consists in heating the product to a temperature greater than the critical one and in letting it remain at such a temperature to subsequently cool it in still air.

The aim of the hardening operation is, as is known, to obtain a high hardness, and such an end is achieved, generally, by heating to above the critical temperature, permanency at such a temperature and very rapid cooling, at least in the initial stage. The hardening with polymorphous transformation is typical of iron-carbon alloys and allows a non-equilibrium structural state to be achieved with a heating to above the phase transformation temperature and with a rapid cooling, while that without a polymorphous transformation, typical for aluminum alloys, consists in heating up to a temperature at which a solid homogeneous solution is obtained and in subsequently rapidly cooling, to obtain a homogeneous supersaturated solution in a structural non-equilibrium state. If the cooling rate is greater than a certain critical value, the polymorphous transformation doesn't take place. According to the treated materials and to the characteristics desired in the final product, the cooling is carried out with different means and modalities, e.g. in still air, in a gaseous stream, with water, with thermal oils, with special cooling liquids.

Tempering and ageing are always practised after hardening: the first consists in a heating of the alloy to below the phase transformation temperature, followed by a slow cooling, in order to decrease the hardness obtained with the hardening and to increase toughness, and the second is a spontaneous tempering which takes place after the hardening without a polymorphous transformation when the product is left at room temperature, or is slightly heated.

Thermal treatments can be divided into primary or secondary depending on whether they are to be followed by further operations or they lead to the final product.

The previously described conventional thermal treatments have various shortcomings and restrictions, which have urged to the research of new possibilities, in the context whereof the present invention inserts itself.

-) in many cases one does not succeed in achieving the desired level of characteristics, or a suitable combination of said characteristics;

-) some kinds of thermal treatments are of a long time duration or considerable energy consumptions, or need for complex and expensive apparatuses;

5 -) the use of thermal oils and cooling liquids for hardening, sometimes necessary to obtain the desired cooling conditions, involves added costs and auxiliary apparatuses, in addition to stocking tanks, and, moreover, makes the characteristics of the working ambient worse and increases the fire risks.

Beside conventional thermal treatments variants have been developed in the last 20-30 years in which one uses special means or techniques for intensifying or modifying the effect of the thermal action. For example, in laser or plasma treatments high heating velocities are achieved, that are reflected on the characteristics of the obtained metallic structure.

Another example of a non traditional treatment of metals is that in which the thermal action is combined with the simultaneous action of mechanical vibrations in the field of sonic or subsonic frequencies (vibrative thermal treatment). The Soviet Patent Application SU-1.497.268, published in 1989, just discloses one of such methods, applied to the treatment of pieces obtained by molding, in particular pistons for internal combustion engines realized with aluminum-silicon-nickel alloys: after the hardening, the ageing is carried out at ambient temperature for 60-90 minutes, applying mechanical vibrations at 600-800 Hz. The end of such a treatment is to increase the plasticity of the final product reducing, at the same time, the energetic consumptions of the process.

20 In vibrative thermal processes the vibrations are generated by proper mechanical devices and transferred to the articles to be treated by means of vibrating bodies.

Both the new mentioned methods and the traditional thermal-mechanical and thermal-chemical treatments are originated by the exigency of obtaining in the finished products combinations of characteristics that are not possible through the only thermal treatment, or by that of rendering the achievement of such characteristics more rapid, cheaper or less harmful for the ambient. However, the addition, compared with exclusively thermal processes, of apparatuses and devices as those necessary for plastically deforming the products, or for imparting mechanical vibrations thereto, or for making metals to absorb the necessary chemical agents, anyhow render the described processes considerably more complex and expensive.

25 The present invention, therefore, aims at extending the possibilities of treatment of metal or metallic alloy products, as well as of the articles obtained therewith, providing a process of a modified thermal type that, though simple and cheap to realize, gives rise to products having mechanical properties considerably better than those achievable with traditional thermal treatments.

The invention has the further aim of improving the technological and economic characteristics of known thermal treatment processes, and of reducing the shortcomings thereof under the ambient standpoint.

30 Such aims are achieved through the arrangement of an essentially thermal treatment wherein, during one or more of the operations that normally such a treatment involves, the product is exposed to the simultaneous action of a pulse gaseous stream of a sufficient power, with a frequency in the sonic field. The use of apparatuses so constructed as to realize the gasdynamic acoustic generator operating principle is suggested to exert such an aeroacoustic action on the metal products to be treated.

40 It is therefore the specific object of the present invention a process for the treatment of products in metallic materials which comprises one or more thermal treatments made up, each, of a stage of heating of the product, one of permanency of said product at a pre-fixed temperature and one of cooling, characterized in that during one or more of said stages said product is exposed to the aeroacoustic action of a pulse gaseous stream in the field of sonic frequencies.

45 Such an aeroacoustic action on the articles to be treated is obtained, according to the invention, by arranging the article at the interior of the resonator of a gasdynamic acoustic generator. Such a generator has to be actuated at the acoustic pressure of at least 150-160 dB, the particular characteristics of sound intensity, frequency and time duration of the treatment being variable according to the composition and the shape of the product to be treated and to the desired final properties.

50 According to a preferred embodiment of the invention, the exposure of the product to said aeroacoustic action is effected during a stage of cooling of said one or more thermal treatments, so as to exploit the pulse gaseous stream both to obtain the desired aeroacoustic action on the article and as a means for cooling. In such an embodiment the pulse air jet can efficaciously substitute the hardening in water or in a thermal liquid, with a considerable simplification of the apparatus.

55 In other cases, the aeroacoustic action provided by the process of the invention can be exerted not during the stage of cooling of a hardening treatment, but during the stage of cooling of a normalizing, tempering or ageing treatment of those conventionally provided in the production cycle.

Alternatively it can be suitable, in some instances, to subject finished products to a supplementary treat-

ment, again reheating the article and letting it remain at the pre-fixed temperature for a certain time duration, to subsequently cool simultaneously exposing the product to the aeroacoustic action according to the invention.

The suggested process can be realized by making use of purposely designed apparatuses that operate in accordance with the principle of the gasdynamic acoustic generators, e.g. of the "whistle" type, or the type of the "static syrens" or of the acoustic generators of Hartmann's type.

The characteristics of the apparatuses utilized to realize the disclosed process are set forth in the relevant claims, and will be described with specific reference to some exemplifying embodiments illustrated in the annexed drawings, wherein:

Figure 1 shows a vertical section view of an embodiment of the apparatus according to the invention, with a detail of the same also represented in an orthogonal view;

Figure 2 shows a vertical section view of a second embodiment of the apparatus according to the invention, and

Figures 3 to 6 show respective realization variants of a part of the apparatus of Figure 2.

Figure 1 represents a device for putting in practice the suggested process in which the pulse gaseous stream is obtained with a "whistle" type gasdynamic generator. During the exposure to the aeroacoustic action the product 1 is arranged at the interior of the resonator 2 of an apparatus which is just so configured as to realize a "whistle" acoustic generator.

The gas is fed under pressure ( $P_0$ ) and at the temperature  $T_0$ , through the feeder 3, endowed with a slit nozzle 4. A wedge shaped blade 5, which also constitutes the upper wall of the resonator 2, finds itself in front of the nozzle 4.

Said resonator constitutes a closed parallelepipedon channel of a rectangular cross section. The gas that passes through the nozzle 4 interacts with the blade 5 giving rise to periodic oscillations: during the first half of the oscillation period the gas passes below the blade 5 going to fill the cavity of the resonator 2 and there increasing the pressure, whereas during the second half of the period the gas flows above the blade 5 and the pressure of the resonator decreases. At the interior of the device, therefore, periodic gaseous vortexes 6 and acoustic oscillations are created.

The fundamental frequency of the resonator 2 is determined by the velocity of the gaseous stream that passes through the nozzle 4, by the height (indicated with 7) of the cavity of the resonator 2 and by the distance (indicated with 8) between the nozzle 4 and the edge of the blade 5.

The product 1, housed in a proper support 9, before being introduced into the illustrated apparatus, is brought and maintained in the furnace at the temperature required by the specific thermal process, for a pre-fixed time interval; then, again together with the support 9, the product 1 is displaced into the apparatus of the invention, introducing it through the opening created by the lowering of the door 10.

Once the door 10 has been closed the pressurized gas is fed to the device and the aeroacoustic action according to the invention is exerted upon the product 1, simultaneously with the cooling in a gaseous stream. In fact, the convection thermal exchange generated by the pulse gaseous flow at the interior of the resonator 2 is sufficient to achieve a rapid cooling.

The duration of the aeroacoustic action according to the process (which in the following will be indicated, for the sake of brevity, with the acronym ATAT, Air Thermal Acoustical Treatment) can vary between one minute and various dozens of minutes, according to the specific exigencies.

In Figure 2 a different embodiment is represented of the apparatus according to the invention, the operation principle whereof is that of Hartmann's type gasdynamic acoustic generator. The apparatus comprises a feeder 11 having a nozzle 12 with a generally circular section, and a resonator 13 of a generally circular section, with a circular upper blade-shaped wedge border 14.

When the gas that comes out of the nozzle 12 at a supersonic velocity interacts with the resonator 13 gasdynamic periodic oscillations are created at the interior of the latter. The limits of the supersonic jet are indicated with 15 in Figure 2, where the typical profile of the shock wave created by the supersonic jet is also shown.

The frequency and the amplitude of the gasdynamic oscillations in the resonator 13 depend on the correlation of the geometrical parameters indicated with 16 to 19 in the figure; the best conditions are attained for a ratio between the diameter 18 of the blade and the diameter 19 of the nozzle 11 equal to 1 to 1.5 and for a ratio between the height 17 of the resonator 13 and the distance 16 from the blade 14 of the resonator to the nozzle 12 equal to 0.5 to 1.0. When equal values of the two diameters and of the height 17 are adopted and air is inlet at ambient temperature the frequency of the oscillation in hertz is equal to  $(6000/\text{nozzle diameter})$ ; where such a diameter is measured in cm. The maximum amplitude of the oscillation is attained for the values of the ratios between the sizes 16 and 17 comprised between 0.4 and 1.5.

The apparatus shown in Figure 2 is utilized arranging the product 20 to be treated at the interior of the resonator 13, and fixing it with the support 21. The first part of the thermal treatment, involving the heating and the permanency at a pre-fixed temperature, is performed with the resonator 13 in position A and subse-

quently, by moving the slid able support plane 22, the resonator 13 is brought in correspond nce with the nozzle 12 and the gas is fed, causing the exposure of the product 20 to the action of the pulse gaseous current.

In Figures 3 to 6 respectively possible variants of the apparatus of Figure 2 are illustrated.

In Figure 3 the product 23 is itself a part of the resonator owing to its particular shape, whereas in Figure 4 the product 24 is a part of the bottom of the resonator, and is heated with a device indicated generally with 25, which can be, e.g., an electric heater. The latter solution is indicated for treatments in which the heating temperature doesn't overcome 200-300 °C.

In Figure 5 a high temperature of heating of the product 26 is realized directly in the resonator by means of an induction heating obtained by making use of the inductor 27. In this case, the resonator is realized in an insulating material. In a further embodiment shown in Figure 6, a cylindrical article 28 of a considerable length is heated by making it to pass through the inductor 29 and then through the resonator of the apparatus according to the invention.

The suggested process has been applied in an experimental way in numerous different ambits, some of which are described in the following examples.

#### EXAMPLE 1

Samples of construction alloy steel of the type 4004 (Italian Standards) or 5140 (U.S.A. Standards) of per cent composition: C-0.45, Cr-1.8, Mn-0.65, Si-0.27, Fe for the balance have been considered.

The traditional thermal treatment of hardening and tempering comprises the heating to a temperature of 840 °C, the permanency in the furnace, the oil-hardening and the tempering at 510 to 560 °C for 1.5 hours.

The treatment realized according to the invention comprised, on the contrary, after the heating and the permanency in the furnace, a hardening realized arranging the products in the acoustic resonator of the invention, cooling with a pulse air jet at the acoustic pressure of 170 dB and with the fundamental frequency of 450 Hz for 5 minutes.

Both in the production with a traditional method and in that with the process of the invention after the hardening a tempering at 550 °C for 1.5 hours has been effected.

The results of the comparative tests of resistance to tensile stress and to shock are reported in the following Table 1.

TABLE 1  
MECHANICAL PROPERTIES

METHOD	ULTIMATE	ULTIMATE		ULTIMATE	RESILIENCY KCU (MJ/m <sup>2</sup> )
	TENSILE	YIELD	ELON-	AREA	
	STRESS	POINT	GATION	REDUCTION	
	$\sigma_B$ (MPa)	$\sigma_{0.2}$ (MPa)	$\delta$ (%)	$\psi$ (%)	
CONVENTIONAL	1140	1050	14	57	1.3
ATAT	1270	1200	15	59	1.3

As can be observed from the data referred in the table, the treatment according to the invention allows to sensibly increase the resistance of the material, leaving the plasticity and resiliency characteristics unchanged.

Another considerable advantage of the suggested process consists in the possibility of avoiding the oil bath for the hardening, which considerably simplifies the necessary apparatus and eliminates the pollution and safety problems connected with the use of the thermal oil.

#### EXAMPLE 2

General purpose drill tips have been considered having a diameter of 4 mm of the spiral and cylindrical types, realized in a free-cutting steel S18-0-2 (DIN, German Standards, per cent composition: C-0.75, W-17.5-18.5; Mo-0.5-0.8; V-1.4-1.7; Co-4.5-5.0; Cr-3.8-4.5) and S6-5-2 (German Standards, per cent composition: C-0.84-0.92; W-6.0-6.7; Mo-4.7-5.2; V-1.7-2.0; Cr-3.8-4.5).

In this case the characteristics of the commercial product as this is normally made available in the market have been compared with those of the product further treated according to the invention, in order to verify the convenience of utilizing the process ATAT as supplementary treatment for finished products.

The supplementary process consisted in heating the drill tips in the furnace to 300 °C (S18) and to 250 °C (S6) and in making them to remain at such a temperature for 30 minutes, to subsequently cool them introducing them into the resonator of a gasdynamic acoustic generator, where they were exposed for 5 minutes to a pulse air flow at the acoustic pressure of 170 dB with the fundamental frequency of 450 Hz.

The results of the mechanical resistance comparative tests, set forth in the following table 2, relate to Rockwell hardness of the drill tips, and to the resistance of the same, defined by the whole quantity of holes of a depth of 12 mm on construction steel C45 (Italian Standards) attainable with the tips under test, considering that attainable with the corresponding non treated commercial tool equal to 100%.

TABLE 2

METHOD	MATERIAL (DIN standards)	ROCKWELL HARDNESS	RESISTANCE
		HRC3	%
CONVENTIONAL	S-18-0-2	63 - 64	100
	S6-5-2	63 - 65	100
CONVENTIONAL+ATAT	S18-0-2	63 - 66	140-160
	S6-5-2	65 - 67	150-180

As can be verified, the treatment according to the invention considerably increases the hardness of the tools, and surprisingly improves their resistance.

A similar increase of resistance (150-300%) has been obtained for tools of other shapes and sizes.

### EXAMPLE 3

The experimentation relates in this case to aluminum alloy samples for molding, of the following per cent composition: Si-7.0; Mg-0.3; other elements-less than the 1.5; Al-the balance.

The thermal treatment traditionally applied to these alloys comprises a heating to 535 °C, a permanency in the furnace for 3 hours and a subsequent water hardening. After the hardening, the material is subjected to natural ageing, with a permanency at ambient temperature for not less than 96 hours, or artificial ageing, with a permanency at about 150 °C for 2 hours.

In the variant suggested according to the invention, the natural or artificial ageing subsequent to the hardening is substituted by the following treatment: 4 hours after the hardening the samples are again heated bringing them to 200-300 °C and leaving them to remain at the pre-fixed temperature for 15 minutes; subsequently, they are arranged in the resonator of a gasdynamic acoustic generator where the cooling is realized in a pulse air stream at the fundamental frequency of 550 Hz and at the acoustic pressure of 165-170 dB, for a time of 3 minutes.

The mechanical characteristics of two series of products according to the invention, one wherein the sample has been heated to 200 °C and one wherein it has been heated to 300 °C, are reported in the following table 3, together with the characteristics of traditional products aged artificially or at ambient temperature.

TABLE 3  
MECHANICAL PROPERTIES

METHOD	ULTIMATE TENSILE STRESS $\sigma_B$ (MPa)	YIELD POINT $\sigma_{0.2}$ (MPa)	ULTIMATE ELONGATION $\delta$ (%)	BRINELL HARDNESS HB (MPa)
CONVENTIONAL with an ageing at T = 20 °C for 96 hours	195	118	3.7	760
CONVENTIONAL with an ageing at T = 150 °C for 96 hours	203	122	3.5	780
ATAT with heating at 200 °C with ageing at T = 20 °C for 96 hours	200	107	7.8	650
ATAT with heating at 300 °C with ageing at T = 20 °C for 96 hours	250	160	3.0	960

The samples in which the aeroacoustic thermal treatment according to the invention comprised a preliminary heating to 200 °C, present, as can be observed from the table, a plasticity increase greater than 200% compared with conventional products, with a reduction of hardness that can be considered of a little significance.

On the contrary, the samples obtained with ATAT and a heating to 300 °C present a tensile strength improved by 20-25 % in comparison with the materials obtained with conventional methods, an as much improved hardness and a certainly negligible decrease of plasticity. It is to be observed that such a combination of characteristics of resistance and plasticity is not attainable with other methods at the present day.

#### EXAMPLE 4

In the present example the possibilities of improving the performance of aluminum alloy commercial products are estimated applying the method of the invention as a supplementary treatment thereto.

Low mechanical resistance aluminum alloy (Al-Si-Mg system) samples for molding have been considered, of the following per cent composition: Si-10-13; other elements less than 2.5; Al-the balance. Such an alloy has optimum properties for the molding and a high resistance to corrosion, but has poor mechanical resistance

properties, and is not subjected to hardening treatments. Generally, aluminum alloy pieces obtained by molding are not subjected to thermal treatments, except, sometimes, a tempering at 300 °C for 5-10 hours in order to eliminate internal stresses.

The mechanical properties of conventional products have been compared with those of similar products subjected, subsequently, to a heating to 300 °C for 15 minutes or to 400 °C for 10 minutes, as well as with those of products obtained applying the method of the invention.

In particular, groups of samples have been heated, respectively, to 300 °C for 15 minutes, to 400 °C for 10 minutes and to 480 °C for 10 minutes and have been subsequently introduced into the resonator of a gas-dynamic acoustic generator, where they have been cooled for 4 minutes with a pulse jet at the acoustic pressure of 170dB and at the fundamental frequency of 400, 550 and 800 Hz respectively.

TABLE 4

## MECHANICAL PROPERTIES

METHOD	HEATING °C; min	ULTIMATE TENSILE STRESS	YIELD POINT	ULTIMATE ELON- GATION	BRINELL HARDNESS
		$\sigma_B$ (MPa)	$\sigma_{0.2}$ (MPa)	$\delta$ (%)	HB (MPa)
CONVENTIONAL	-	127	90	1.8	500
CONVENTIONAL+	300; 15	114	81	2.0	500
HEATING	400; 10	100	76	2.2	480
CONVENTIONAL+	300; 15	185	115	2.1	650
HEATING+	400; 10	180	121	2.0	630
ATAT	480; 10	173	112	2.3	600

The values provided by the table show that a supplementary surface treatment according to the invention allows the mechanical strength of obtainable aluminum alloy products to be increased of about the 30%, though not sensibly altering the plasticity characteristics thereof.

The present invention has been disclosed with particular reference to some its preferred embodiments, but it is apparent that variants or modifications can be made by those skilled in the art, without so departing from the scope of the enclosed claims.

## Claims

1. A process for the treatment of metallic material articles comprising one or more thermal treatments, each made up of a stage of heating of the article, one of permanency of said article at a prefixed temperature and one of cooling, characterized in that during one or more of said stages said article is exposed to the aeroacoustic action of a pulse gaseous stream in the field of sonic frequencies.
2. The process according to Claim 1, wherein said aeroacoustic action is obtained by means of a gasdynamic acoustic generator, in the resonator whereof the article to be treated is arranged.
3. The process according to Claims 1 or 2, wherein said aeroacoustic action exerted upon said article involves a pressure of at least 150 dB.
4. The process according to any one of Claims 1 to 3, wherein a stage of cooling of said one or more thermal treatments is realized with a simultaneous exposure of the article to said aeroacoustic action by a pulse

gaseous stream.

5. The process according to Claim 4, realizing a hardening treatment in air.
- 5 6. The process according to Claim 4, realizing a tempering, ageing or normalizing treatment.
7. The process according to Claim 4 realizing a supplementary process, made up of a stage of a further heating of the finished article, one of permanency of said article at a prefixed temperature and one of cooling with a simultaneous exposure of the article to said aeroacoustic action by a pulse gaseous stream.
- 10 8. An apparatus for the treatment of metallic material articles comprising a gasdynamic acoustic generator endowed with a resonator suitable to house said articles to be treated at its interior.
9. The apparatus according to Claim 9 comprising a resonator in the shape of a parallelepipedon chamber endowed with a movable opening for the passage of said articles, a pressurised gas feeder endowed with  
15 a nozzle in the shape of a slit and a wedge blade arranged with its edge in correspondence with said slit, said blade being a part of the upper wall of said parallelepipedon chamber.
10. The apparatus according to Claim 8, comprising a Hartmann's type gasdynamic acoustic generator.
- 20 11. The apparatus according to Claims 8 or 10 comprising a pressurized gas feeder endowed with a circular nozzle and a resonator in the shape of an upperly open cylinder, with its upper edge cut in the shape of a wedge to form a circular blade and arranged in correspondence with said circular nozzle, at a prefixed distance from the same.
- 25 12. The apparatus according to any one of Claims 8 to 11 wherein said article to be treated constitutes, during the treatment, a part of the walls of said resonator.

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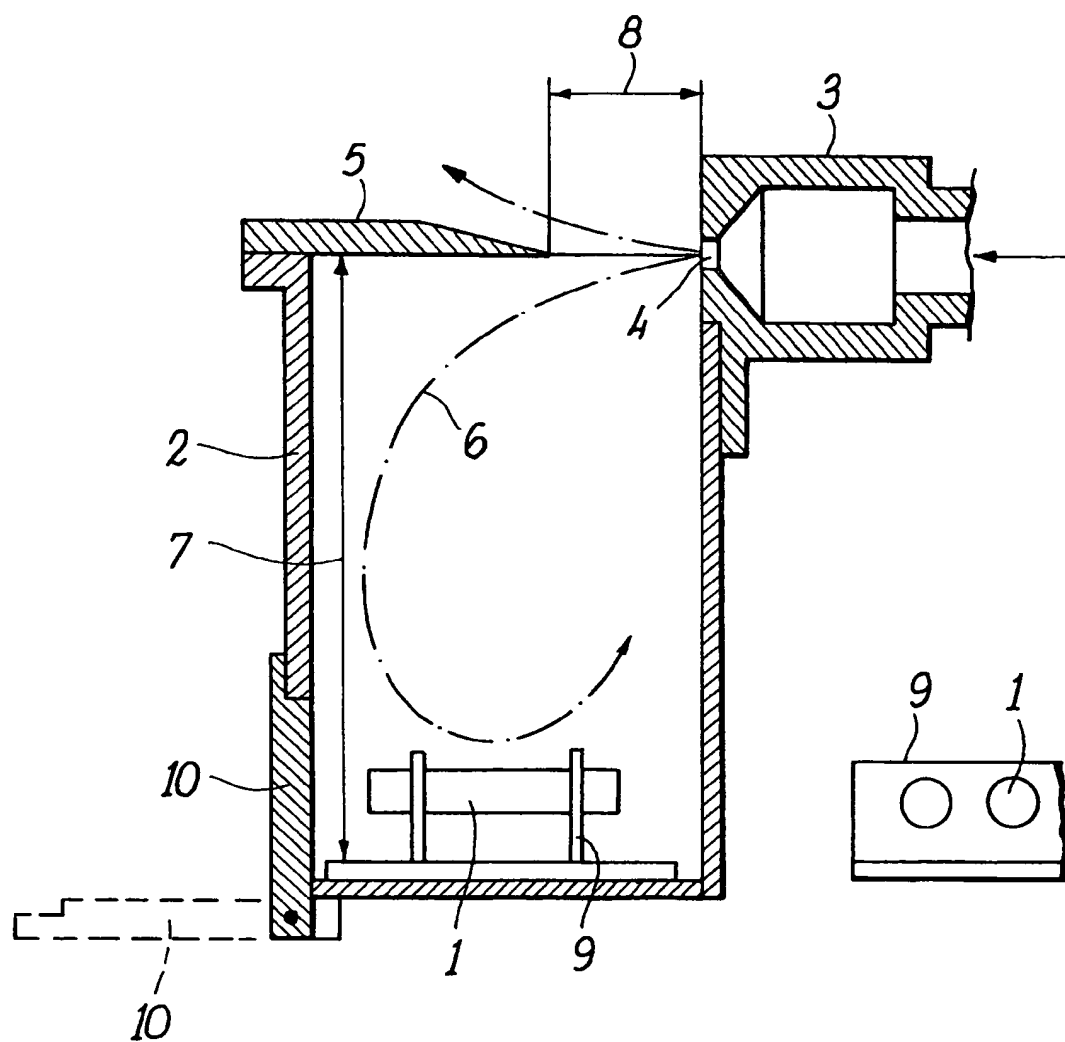


FIG. 1

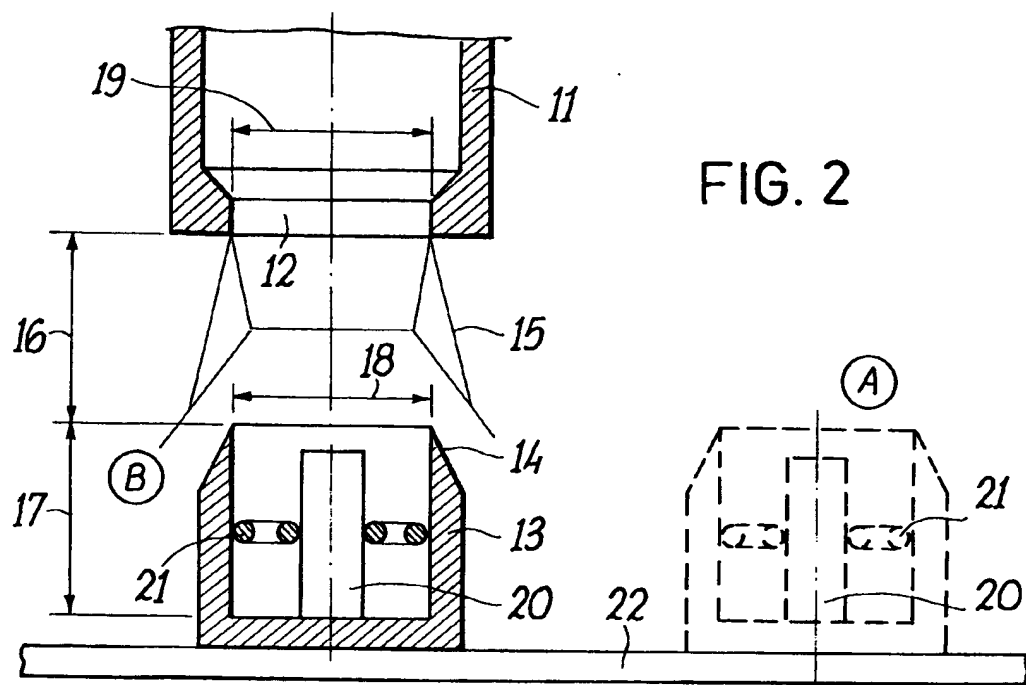


FIG. 2

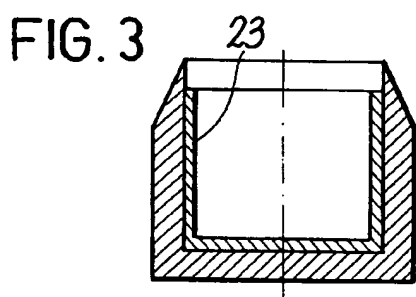


FIG. 3

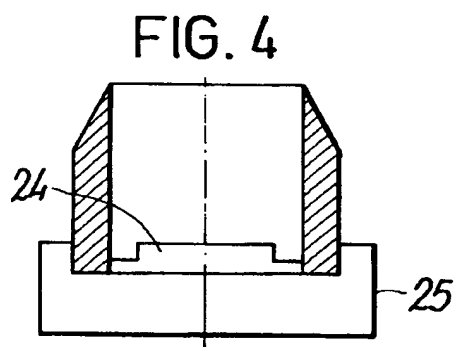


FIG. 4

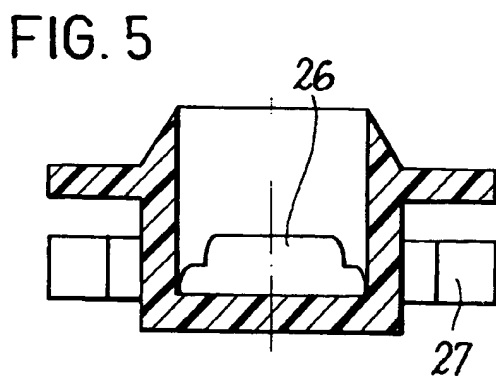


FIG. 5

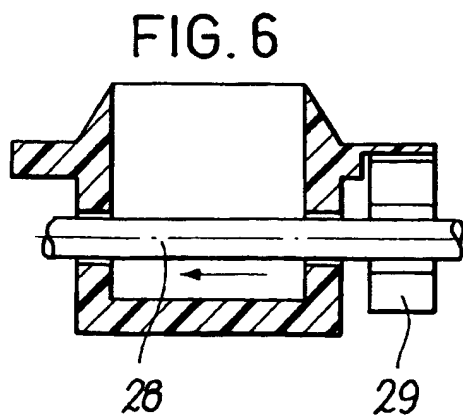


FIG. 6



European Patent  
Office

# EUROPEAN SEARCH REPORT

Application Number

EP 92 83 0325

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
X	STAHL UND EISEN, vol. 109, no. 13, 3 July 1989, DUSSELDORF DE page 623; N. N.: 'Walzdrahtkühlung mit Infraschall'	1	C21D1/04
A	WD-A-9 005 275 (INFRASONIK) * claims 1,5 *	1	
A	DE-C-767 719 (DORTMUND-HOERDER HUTTENVEREIN) * claim 1 *	1	
A	FR-A-1 093 064 (D. NAPIER & SON) * page 3 *	1	
A	US-A-3 276 918 (B. LANGENECKER) * claim 1 *	1	
A	US-A-3 398 944 (R. M. G. BOUCHER) * figure 1 *	1	
			TECHNICAL FIELDS SEARCHED (Int. Cl.5)
			C21D F28F C22F C21C
The present search report has been drawn up for all claims			
Place of search BERLIN		Date of completion of the search 31 AUGUST 1992	Examiner SUTOR W.
<p><b>CATEGORY OF CITED DOCUMENTS</b></p> <p>X : particularly relevant if taken alone  Y : particularly relevant if combined with another document of the same category  A : technological background  O : non-written disclosure  P : intermediate document</p> <p>T : theory or principle underlying the invention  E : earlier patent document, but published on, or after the filing date  D : document cited in the application  L : document cited for other reasons</p> <p>&amp; : member of the same patent family, corresponding document</p>			

EP0 FORM 1500 (04.92) (P0001)